The Butler Oscillator

By B. PRIESTLEY, G3JGO*

THE advantages of overtone operation of crystal oscillators are well known but unfortunately a reputation for unreliability discourages some amateurs from using them. The following notes on the design and practical results are intended to show what the circuit can, and cannot be expected to do.

A quartz crystal, near its resonant frequencies, fundamental or overtone, has the equivalent circuit of Fig. 1 where R, the equivalent series resistance (e.s.r.) is about 50 to 100 ohms for an h.f. overtone unit. Ignoring the effect of the holder capacitance C_h, we know that if the crystal were

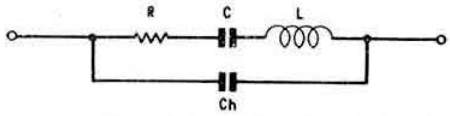

Fig. 1. Equivalent circuit of a quartz crystal near resonance.

connected across the output of a signal generator, the r.f. current flowing would show a sharp peak at the resonant frequency, where only R limits the current. However, if a 20K ohms resistor is connected in series with the crystal, the rise in current at resonance would be much less spectacular, and in practice could be completely masked by the current through the holder capacitance. As this series resonant

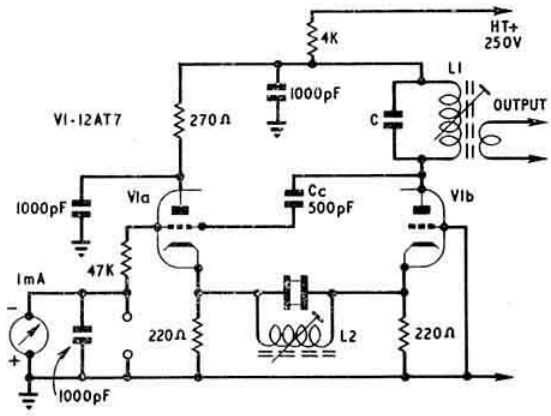

Fig. 2. Standard Butler Oscillator circuit.

mode is almost universal in overtone operation, to give the crystal control it is most important to work between a low resistance source and load, and to bear in mind and possibly neutralize the holder capacitance.

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In the circuit of Fig. 2, the low source impedance is provided by a cathode follower $V1_a$ and the low load impedance by an earthed grid amplifier $V1_b$. Cross coupling is provided by C_c to maintain oscillation. L1 and C are resonant at the overtone frequency, but should provide only sufficient selectivity to guarantee the correct overtone, so that the crystal alone determines the working frequency. For this reason it is desirable that C should be simply the stray capacities. When extreme stability is required, a damping resistor across the tuned circuit is recommended.

L2 tunes out the holder capacitance, typical values for the latter being 40pF for a 10X unit, 15pF for FT243 and 7pF for HC-6/U. This component may not be essential with modern overtone units, but is necessary with non-overtone units of high capacitance and high e.s.r. Again, for extreme stability, it should be shunted by a resistor of 500-1000 ohms.

Practical Results

Using the circuit shown, it was found quite straightforward to persuade surplus FT243 units to take off on their fifth overtone around 35-36 Mc/s, provided L2 was used and adjusted to prevent self-excited operation. (If this seems remarkable, a report prepared by Philco for the US army reports successful ninth overtone operation with careful circuit design. A 14 Mc/s crystal was used!) The output

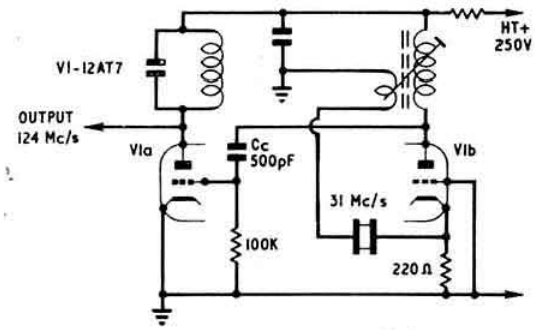

Fig. 3. Squier oscillator and multiplier.

was not very great, but was perfectly adequate to drive an EF91 or similar valve.

A modification to the circuit was the inclusion of a circuit tuned to a harmonic of the overtone in the cathode follower anode circuit. This was tried, with a view to reducing the number of stages of multiplication in a 145 Mc/s converter. During setting up it was found that the frequency tended to jump, and it was realized that the crystal dissipation was excessive, for if the e.s.r. is 50 ohms, the maximum (r.f.) current is 6mA for the dissipation to be kept within the typical 2mW limit, and so the h.t. was reduced to about 200V which eliminated the instability. However, this also reduced the harmonic output to very low proportions, because the cathode follower is operating under class AB2 conditions. Thus it seems desirable to generate harmonics in a following stage if frequency stability is at all critical, even with crystal units capable of greater dissipation.

As the writer had insufficient space in a prototype unit for additional valves, one half of the 12AT7 was re-wired as a Squier oscillator working on the same principles, leaving the other half free for use as a quadrupler (Fig. 3). This gave much more output at 124 Mc/s and a stability adequate for G3MED's s.s.b.! though possibly not good enough for moonbounce!

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The Effective use of Low Pass Filters for Reducing TVI

By G. P. ANDERSON, AMIEE, G2QY*

A FEW years ago the writer was involved in some investigations into the reduction of TVI from high power transmitters, and some of his experiences may be of interest to other amateurs faced with similar (but lower power) problems. Although much has been written about TVI and how to overcome it, several features the writer has not seen in print came to light during the work.

Despite care in design, some harmonic energy will be produced in a transmitter, and surprisingly little is needed to spoil a picture, especially in areas of low TV signal strength. The principal step, which cannot be over-emphasized, is complete screening of the transmitter, so that the only outlet for r.f. of any frequency is through the aerial connection. Therefore, screen and filter all supplies as well as the transmitter itself—and this includes power, key, microphone and meter leads. Information on these points is given elsewhere, and naturally the extent of the filtering needed will depend upon the strength of the TV signal.

The transmitter in the case under review was already well screened and filtered, and as a first trial tuned traps had been inserted in the output leads to the aerial. These certainly reduced the interference, but being essentially single frequency devices, they had to be retuned each time the transmitter frequency was changed. The obvious solution was a low pass filter—no novelty to the amateur, but as far as the writer was concerned the novelty lay in the kW instead of watts.

A suitable filter was designed and fitted inside a copper box with terminals on either end; it was to work into 600 ohm open wire line, and laboratory measurements showed attenuation of more than 60 db at frequencies above 40 Mc/s.

Owing to the particular position of the transmitter used for the tests, it was convenient to mount the filter horizontally on the top of the cabinet, and to make the connections to the output terminals of the transmitter through about 18 in. of wire. As already mentioned, the transmitter was very well screened, and the filter box was firmly bonded to it, and consequently to earth. The output of the filter was connected through 600 ohm feeder line to a correctly terminated rhombic aerial, and measurements were made to see if any harmonics were getting through. They were; in fact, as a result of tests at a number of locations up to two or three miles away it soon became apparent that in some places the harmonic level was increased by the introduction of the filter—not at all " according to the book." It was also observed that the effectiveness of the filter on various harmonics was different at different sites.

To cut a rather long story short, further tests showed that this effect was due to direct radiation from the transmitter and associated wiring, plus radiation from the aerial system, of harmonics that had bypassed the filter. The variation in effectiveness (or lack of it) of the filter in different places was due to the " interference pattern " of the signals arriving by different routes and with phase conditions disturbed by the introduction of the filter.

The cure was obtained by eliminating the few inches of open wire line between the transmitter output terminals and the filter by mounting the filter so that it became essentially part of the transmitter cabinet, and the output terminals of the filter became the output terminals of the transmitter. It was then impossible to detect any harmonic energy even quite close to the transmitter itself.

The lesson learned was that, having satisfied oneself that the filter is producing the desired attenuation by means of measurements on the bench, should its effectiveness at the television receiver be in doubt, a check should be made into the thoroughness of the bonding into the transmitter. Even an inch or two of exposed line between the transmitter and the filter, or r.f. on power feeds, key or microphone leads, can allow harmonic energy to get on to the aerial, or house wiring, and so ruin the performance of the filter.

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Possible Developments

The Butler circuit can also be used to generate the fundamental frequency, in which case the tuned circuit can be replaced by a choke or resistor. It is particularly useful for sluggish, low frequency units.

The conventional double triode may be replaced by a triode pentode, using the pentode as an electron-coupled amplifier to obtain a greater output.

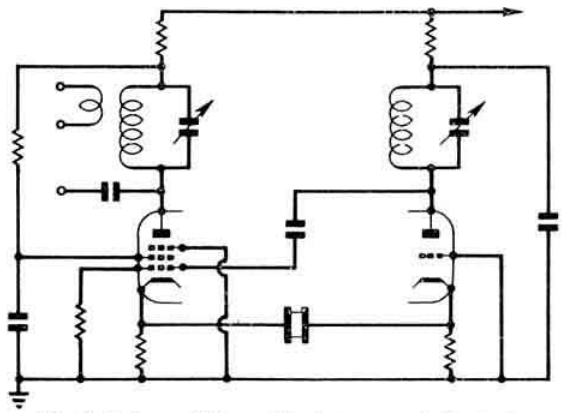

Fig. 4. Butler oscillator with electron coupled output.

Conclusion

Experiments have shown that the Butler is a reliable overtone oscillator, even with surplus crystals, and is capable of good stability. It is simpler than the Squier, needing no adjustment of transformer ratios, but at the expense of another triode. In common with all precision oscillators it is not intended to deliver high power output.